CHAPTER 4: NSSL ALGORITHMS

The NSSL algorithms are designed to detect and analyze severe weather events. By processing Doppler radar data, the NSSL algorithms produce product information for display in RADS. Text files are also produced for more quantitative evaluation.

The various NSSL algorithms included in WATADS are:

- **S**torm **C**ell **I**dentification and **T**racking **(SCIT)** Algorithm
- **H**ail **D**etection **A**lgorithm **(HDA)**
- **M**esocyclone **D**etection **A**lgorithm **(MDA)**
- **T**ornado **D**etection **A**lgorithm **(TDA)**
- **B**ounded **W**eak **E**cho **R**egion (BWER) Algorithm
- **D**amaging **D**ownburst **P**rediction and **D**etection **A**lgorithm (DDPDA)
- **N**ear-**S**torm **E**nvironment (NSE) Algorithm
- **L**ightning **A**ssociation **A**lgorithm (LAA)
- WSR-88D Precipitation Algorithms
- **V**ertically **I**ntegrated **L**iquid (VIL) Algorithm

The NSSL Storm Cell Identification and Tracking (SCIT) Algorithm

1. Purpose

The purpose of this document is to describe the NSSL Storm Cell Identification and Tracking (SCIT) algorithm, how to interpret the products shown on the Radar Algorithm and Display System (RADS).

Full details of how information is displayed using RADS is contained within the WDSS User Manual. The WDSS User Manual should be used as a supplement to this document, particularly the sections on overlays, tables, and trends for the SCIT algorithm.

2. The Algorithm

The Storm Cell Identification and Tracking (SCIT) Algorithm is an enhanced version of the pre-Build 9.0 WSR-88D Storm Series Algorithms. The SCIT algorithm's development was motivated by the often poor performance of the WSR-88D Storm Series Algorithms in situations of closely spaced storms (i.e., lines, clusters). The use of seven reflectivity thresholds to identify storm cells in the SCIT algorithm, rather than one in the WSR-88D Storm series algorithm, greatly improves the algorithm's performance. For instance, within a line or cluster of storms, individual storm cells are detected by the SCIT algorithm, whereas only one storm system may be detected by the WSR-88D Storm series algorithm.

Since individual storms, rather than storm systems, are defined by the SCIT algorithm, individual storm cells may be tracked. In addition, individual storm cell characteristics, such as cell-based VIL, may be determined and trended. Thus, the evolution of cell-based characteristics is available to the forecaster. Short-term storm cell movement forecasts are also determined. Positional and other cell-based attributes are displayed on RADS. Algorithm output is available in the form of storm cell overlays, a storm cell table, and storm cell-based trend plots.

In order to understand this algorithm output, the user must have a basic understanding of a SCIT-defined storm cell. Storm cell definition is achieved through a three-dimensional processing of reflectivity data. First, for each elevation scan, storm segments are identified which meet length requirements (default 1.9 km) along a radial and have contiguous range gates with reflectivities above one of seven reflectivity thresholds (30, 35, 40, 45, 50, 55, 60 dBZe) are identified. Individual storm segments that are close azimuthally and overlap in range by approximately 2 km are combined into two-dimensional (2D) storm components. When less intense (lower reflectivity) components overlap with more intense (higher reflectivity) components, only the most intense components are analyzed.

Once all the 2D components have been defined, they are associated in the vertical, to define three-dimensional (3D) storm cells. Two-dimensional components are vertically associated if their centroids are located at vertically adjacent elevation angles and their centroids are horizontally within 5, 7, or 10 km of each another. Since only the most intense components are used to define 3D storm cells, the final product is actually a 3D storm cell centroid. Further details are available in Johnson et al. (1998).

3. SCIT Output

A. Cell Overlays

The cell overlays identify each storm cell's location, past storm tracks, and short-term forecasted storm movement. Detected storm cells are represented by identification numbers enclosed in boxes. The storm cell centroid location (azimuth and range from the radar) represents the position of the lowest 2D component which comprises the cell. This position usually corresponds to the location of the storm cell's maximum reflectivity at the lowest elevation angle (0.5). Only the strongest 20 storm cells within the domain of any image are displayed. When using the zoom feature, more cell IDs may appear, such that the strongest 20 cells within each zoomed image are displayed.

The past tracks of a storm cell are indicated by white lines and dots, which represent the cell's position at previous volumes scans up to 30 minutes before the current volume scan. Predicted storm cell movement within the next thirty minutes is displayed as magenta cross-hairs, each representing a five-minute interval. The total predicted storm cell movement time is related to the storm lifetime; after an algorithm-defined storm cell has existed for at least five minutes, a five-minute storm movement prediction is generated. Once the same storm cell has existed for at least ten minutes, a ten minute storm movement prediction is generated, and so on. The method used to determine these storm movements is a linear-least squares fit of the storm cell's current and previous 3D mass-weighted centroid locations, with mass-weighting calculated relative to the cell's entire volume. Witt (1992) determined that optimal tracking performance may be gained by using five past centroid locations in this calculation (Witt 1992). Equal weight is given to all past centroids.

B. Cell Table

The cell table summarizes the algorithm detections and cell-based attributes associated with the twenty strongest cells, as defined by the algorithm. Cell strength is determined by the summation of three weighted parameters:

cell strength = circulation type*109 + hail index*105 + damaging wind index

where the hail index is a function of the summation of estimated hail size, the probability of severe hail and the maximum reflectivity. Thus, the order of cells in the cell table depends on the storm type and the presence and size of hail and damaging winds. For example, because the circulation type is given the most weight, if a mesocyclone is detected by the Mesocyclone Detection Algorithm (MDA), the associated cell will most likely be listed at the top of the cell table. The ranking of these parameters may be changed by the user in the ssaparm.dat file.

In addition to showing the twenty strongest storms, the cell table displays cell-based attributes and detected or predicted signatures related to severe weather phenomena from the MDA, Tornado Detection Algorithm (TDA), Hail Detection Algorithm (HDA), and the Damaging Downburst Prediction and Detection Algorithm (DDPDA). Further description of attributes determined by these other algorithms is available in their associated documentation. Below is a listing of each attribute, moving across the table from left to right, followed by a brief description and units when applicable.
Attributes denoted by * are available for display as cell trends (see section C). Note that the height products are all relative to the height of the radar, above radar level (ARL). Units may be changed from metric to English using the Preferences menu in RADS.

CID - Cell identification number

AZ/RAN - Azimuth and range, relative to the radar, of the cell centroid overlay (degrees/km, nm)

CIRC - Type of circulation signature (including tornadic)

BURST - Predicted or detected downburst

SVRH - Probability of severe hail (%)

SIZE - Maximum expected hail size (inches)

HAIL - Probability of any size hail (%)

*VIL - Vertically integrated liquid water content (kg/m2); an integration of the equivalent liquid water in a column. Cell-based VIL is determined by integrating, throughout the depth of the storm, the average (three-gate) maximum reflectivity associated with each 2D component that comprises a 3D storm cell (Johnson 1992). Large values of VIL have been related to severe thunderstorms (Greene et al. 1971).

*MAXZ - Maximum three-gate reflectivity average, with respect to all 2D components (dBZe). High reflectivity values may indicate heavy rain and possibly hail.

*HT MXZ - Height of maximum dBZe value (height of the cell's maximum reflectivity core), determined by the height of the 2D component containing the maximum reflectivity value (km, kft). The maximum reflectivity core tends to descend as a storm begins to collapse.

*BASE - Base of the storm cell, determined by the height of the lowest 2D storm component comprising a 3D storm cell (km, kft). A relatively high (low) cell base may indicate that a storm is developing (dissipating) or that elevated convection is occurring.

*TOP - Top of storm cell, determined by the height of the highest 2D storm component comprising a 3D storm cell (km, kft). High storm tops tend to indicate strong updrafts.

DIR - Direction from which a storm cell is moving, calculated using the u and v storm cell vectors determined by a least squares fit method (degrees)

SPD - Speed at which a storm cell is moving, calculated using the u and v storm cell vectors determined by a least squares fit method (m s-1, kts)

*SREH - Storm-relative helicity (m2 s-2), defined as twice the signed area swept out by the storm-relative wind vector over the depth of the inflow, (assumed 0-3 km). The storm-relative helicity values are determined using RUC II model wind values (0-3 km AGL) combined with SCIT-derived cell motion estimates. Helicity is useful in measuring rotational potential (Davies-Jones et al. 1990).

C. Cell Trends.

Cell trends are plots showing values of given attributes associated with a storm cell for up to the last ten volume scans. Attributes denoted by a * in the previous section are all available for display as individual trends, time-height charts, or in the trend set. Fifteen cell-based trended attributes are available from the cell menus. Descriptions of the SCIT- calculated attributes are given below; other attributes are described in their corresponding documentation.

STORM MASS - Estimated storm cell mass-weighted (or equivalent liquid water content-weighted) volume (kg). The storm mass is determined by summing the mass of each 2D component comprising a 3D cell. The reflectivity associated with each sample volume (gate or bin) that comprises a 2D component is included in this calculation. Meteorologically, a continuous increase (decrease) in storm mass indicates that a storm is intensifying (dissipating), since a strong inflow (outflow) and updraft (downdraft) increases (decreases) the liquid water content in a storm cell.

CELL VOLUME - Storm cell volume, determined by summing the volume occupied by each 2D component comprising a 3D storm cell (m3). Meteorologically, a continuous increase (decrease) in cell volume tends to indicate that a storm cell is intensifying (dissipating). A storm cell whose 3D volume increases over a long period of time may suggest that the storm is able to overcome dry air entrainment.

CORE ASPECT RATIO - The ratio of storm depth to storm width, where storm depth is the height difference between the storm top and the storm base, and storm width is the width of the 2D component containing the maximum reflectivity value. This attribute is a measure of storm cell intensification and dissipation. For instance, as a storm intensifies, its shape is more like a column (depth > width); as a storm dissipates, its shape is more like a mushroom (depth <width).

CENTER OF MASS HEIGHT - Height of the storm cell's center of mass (km, kft). This value may be interpreted as the estimated height of the storm cell's maximum reflectivity core. This attribute uses a slightly different approach than the HT MXZ to determine the height of the maximum reflectivity core.

4. Other information

It is important to remember that algorithm products are not available to the user until the end of the volume scan, which is 5-6 minutes later than the lowest-tilt image which can be viewed from that volume scan. Thus, the corresponding centroid position is also 5-6 minutes old when it is available for display. This restriction should be taken into consideration when forecasting the position of the storms in warnings. For example, use the magenta cross-hairs to forecast the position of an centroid at a future time HHMM rather than "xx minutes from now." Users should also keep in mind that RADS displays the centroid of the storm cell, and sometimes severe weather occurs near the leading edge of the storm cell or along the gust front outflow.

The WSR-88D Operations Course also pointed out several limitations of the base reflectivity and velocity data. These limitations should influence the interpretation of algorithm products, especially within the "cone of silence" and beyond approximately 125 nm from the radar.

The NSSL SCIT and RADS contain many features which are unavailable in the current WSR-88D package. The goal of creating these features is to provide better information to guide the decisions of warning forecasters. Any feedback which can be provided about the usefulness of the NSSL SCIT algorithm would be greatly appreciated, and would enhance the creation of future versions of the algorithm.

5. References

Davies-Jones, R., D. Burgess, and M. Foster, 1990: Test of helicity as a tornado forecast parameter. Preprints, 16th Conf. on Severe Local Storms, Kananaskis Park, Atla., AMS, 588-592.

Greene, D.R., and R.A. Clark, 1971: An indicator of explosive development in severe storms. Preprints, 7th Conf. on Severe Local Storms, Kansas City, MO, AMS, 97-104.

Johnson, J.T., 1992: Investigation of outflow strength variability in Florida downburst-producing storms. M.S. Thesis, University of Oklahoma, 172 pp.

Johnson, J.T., P.L. MacKeen, A. Witt, E.D. Mitchell, G.J. Stumpf, M.D. Eilts, K.W. Thomas, 1998: The Storm Cell Identification and Tracking (SCIT) algorithm: An enhanced WSR-88D algorithm. Wea. Forecasting, 13, 263-276.
____, 1992: An enhanced storm cell identification and tracking algorithm for the WSR-88D. OSF Report, 18 pp.

The NSSL Hail Detection Algorithm (HDA)

1. Purpose

The purpose of this document is to describe the NSSL Hail Detection Algorithm (HDA), and to discuss interpretation of the output shown in RADS.

Full details of how information is displayed using RADS is contained within the WDSS User Manual. The User Manual should be used as a supplement to this document, particularly the sections on overlays, tables, and trends for the HDA and Storm Cell Identification and Tracking (SCIT) algorithm.

2. The Algorithm

The purpose of the NSSL Hail Detection Algorithm (HDA) is to provide reliable estimates of the probability of hail, probability of severe hail, and the maximum expected hail size for each storm cell identified by the NSSL Storm Cell Identification and Tracking (SCIT) algorithm (Johnson et al. 1998). The HDA is composed of two sub-algorithms: the Hail Core Aloft Algorithm (HCAA) (Witt 1990, 1993) and the Upper-Level Divergence Algorithm (ULDA). The HCAA produces all of the HDA output. Output from the ULDA can be viewed in the hail trend plots and is used as input for other algorithms in the Warning Decision Support System.

3. HDA and WSR-88D Hail Algorithm Functional Comparison.

The NSSL HDA and Build 9.0 WSR-88D Hail Algorithm are identical with the following exceptions:

1) The NSSL HDA runs the ULDA sub-algorithm,

2) The NSSL HDA takes input from the NSSL SCIT Algorithm which has minor differences than the Build 9.0 WSR-88D SCIT Algorithm, and

3) The NSSL HDA uses thermodynamic information from the RUC II model rather than from user input (although user input can override the automatic input).

4.) The NSSL HDA uses relative humidity data to better model the environmental effects of hail melting.

4. Use of HDA output.

The NSSL HDA calculates three parameters: probability of hail, probability of severe hail, and maximum expected hail size. The following suggestions are given concerning the use of HDA output:

Probability of hail (POH)

The POH parameter determines the probability of any size hail, including severe hail, associated with a given storm cell. The POH parameter was developed using data from a High Plains environment. Until additional analysis is done, the prob ability values should be used with caution when applied in other environments.

Probability of severe hail (POSH)

The POSH parameter determines the probability of severe hail, i.e., hail with a diameter   1.9 cm (0.75 in.) This parameter has undergone extensive development in a wide variety of environments, but is still undergoing testing and optimization. The POSH parameter has been calibrated to the data analyzed thus far, with a POSH of 50% corresponding to the highest overall Critical Success Index (CSI) for all storm days. However, since this correspondence is a function of the verification efficiency, it may not always be best to base warning decisions solely on a threshold of 50%. In situations where a storm is located in relatively open country, a higher threshold may be better, while in situations where a storm is approaching a heavily populated area, a lower threshold may be better.

Maximum expected hail size (SIZE)

This estimate refers to the maximum expected hail size anywhere in the storm. Since the largest hail tends to fall in a narrow swath near the updraft, a single hail report will often not be representative of the largest size being produced by the storm at that time. The SIZE parameter was developed such that 75% of severe hail reports should be below the size estimates, with size underestimates penalized more than overestimates. Therefore, an overall high bias in the SIZE relative to the majority of severe hail reports received should be expected.

HDA output can be displayed in tabular format in the Cell Table, graphically as icons on the radar images, and in trend plots. The Cell Table contains the values of POH (labeled HAIL), POSH (labeled SVRH), and SIZE for each storm cell detected by SCIT. The HAIL and SVRH columns show probabilities ranging from 0% to 100%, in 10% increments. Probabilities greater than 50% are displayed with a red background, probabilities between 10% and 40% with a yellow background, and 0% probability with a green background. This coloration of the HDA output allows the user to quickly glance at the table and get a general idea of the hail threat associated with each storm cell shown in the table, without having to actually read all the numerical values. The SIZE column shows maximum expected hail diameter in inches, in increments of 0.25 inch. All size estimates less than 1 inch are shown by the symbol " < 1.00 ", with size estimates greater than 3 inches shown by " > 3.00 ." Size estimates greater than 2 inches are displayed with a red background, sizes between 1 and 2 inches with a yellow background, and sizes less than 1 inch with a green background. *Note too that POSH (SVRH) values are one of the parameters used to rank cells in the Cell Table*.

HDA overlay icons are combined with the SCIT cell ID overlays. Each SCIT cell ID overlay has a colored rectangular background based on its POSH. The colors used for the overlay are the same as those used in the Cell Table for SVRH.

A cone-of-silence flag is included in the NSSL HDA to alert users to situations when a storm is too close to the radar for it to be fully scanned. The flag is triggered if a detected storm cell has a 2-D component observed at the top elevation angle of the Volume Coverage Pattern (19.5) with a maximum reflectivity of 45 dBZ or higher. If this happens, the HDA output in the Cell Table is highlighted with a purple background, indicating that the output is likely underestimating the hail threat.

HDA output can also be viewed via trend windows. The most useful trend window is the Hail Trend Set, which displays the past trend (for up to one hour) of POH, POSH, SIZE, maximum storm-top divergence (velocity difference) and cell-based VIL for a given storm cell.

5. Other information

The NSSL HDA and RADS contain many features which are unavailable in the current WSR-88D package. The goal of creating these features is to provide better information to guide the decisions of warning forecasters. Any feedback which can be provided about the usefulness of the NSSL HDA would be greatly appreciated.

6. References

Witt, A., 1990: A hail core aloft detection algorithm. Preprints, 16th Conf. on Severe Local Storms, Kananaskis Park, Alta., Amer. Meteor. Soc., 232-235.

_____, 1993: Comparison of the performance of two hail detec tion algorithms using WSR-88D data. Preprints, 26th Intl. Conf. on Radar Meteorology, Norman, OK, Amer. Meteor. Soc., 154-156.

_____, M.D. Eilts, G.J. Stumpf, J.T. Johnson, E.D. Mitchell, and K.W. Thomas, 1998: An enhanced hail detection algorithm for the WSR-88D. Wea. Forecasting, 13, 286-303.

The NSSL Mesocyclone Detection Algorithm (MDA)

1. Purpose

The purpose of this document is to describe the NSSL Mesocyclone Detection Algorithm (MDA), how to interpret its output, and the advantages of and differences between the NSSL MDA and the Mesocyclone Algorithm currently being used with the WSR-88D.

Full details of how information is displayed using the Radar and Algorithm Display System (RADS) is contained within the WDSS User's Guide. This guide should be used as a supplement to this document, particularly the sections on overlays, tables, and trends for the MDA.

2. The Algorithm

The NSSL MDA has been under development since 1993. The first version of the algorithm was delivered to the WSR-88D Operational Support Facility (OSF) on July 15, 1995, and has been used in Warning Decision Support System (WDSS) Proof-of-Concept tests (PoCT) in Phoenix (1994), Fort Worth (1995), Atlanta (1995), and in Indianapolis, Minneapolis, Charleston SC, and Melbourne in 1996. The current version is slightly modified from the version delivered to the OSF.

The NSSL MDA has been developed to address several shortcomings of the WSR-88D Mesocyclone Algorithm (88D-Meso), namely the high false alarm ratio and the failure to detect unconventional mesocyclones, such as low-topped mesocyclones. The algorithm also attempts to detect storm-scale vortices which fail to meet defined criteria for "mesocyclones," but still produce severe weather or tornadoes.

Therefore, the new paradigm used in the NSSL MDA is to have the algorithm detect storm-scale vortices of various dimensions and strengths — not only those meeting mesocyclone criteria — and then to diagnose those vortices further to determine whether they may be associated with severe weather or tornadoes on the ground.

Diagnosis is done in several ways. One way uses "Rule Bases" which attempt to classify the vortices into one of several categories. Another way is via a Neural Network (NN) which computes the Probability of Tornado (POT) and Probability of Severe Weather (POSW) associated with the vortex. Finally, other diagnostic strength parameters which are available in the NSSL MDA are the Strength Rank and the Mesocyclone Strength Index (MSI). All of these parameters are described in further detail in the next section.

The NSSL MDA is not perfect, but it does represent an improvement in skill over the 88D-Meso. Testing and evaluation of the NSSL MDA with 22 storm cases (from various geographic locations in all 4 NWS regions) show an improvement in skill over the 88D-Meso, as evidenced by a higher Critical Success Index (CSI) (the CSI is double that of the 88D-Meso).

But the NSSL MDA gives the warning forecaster more than just better skill scores. By detecting vortices from their incipient signatures, through maturity, and on to demise, the NSSL MDA can accurately associate the vortices in time, thus producing more valuable diagnostic information.

These include tracking information (i.e., Storm Series algorithm) and trends and time-height trends of various strength parameters associated with the vortex. This additional information provides the warning forecaster with valuable guidance in making more informed and more accurate warning decisions.

3. Comparison to WSR-88D Mesocyclone Algorithm (88D-Meso) and use of output in making warning decisions.

The WDSS User's Guide contains color figures and explanations which supplement this section.

The NSSL MDA detects a wider spectrum of vortices than the 88D-Meso on the storm-scale (1-10 km in diameter), and diagnoses them in many ways. Two strength parameters are computed:

1) Strength Rank: A non-dimensional number based on three strength parameters (rotational velocity, shear, maximum gate-to-gate velocity difference). Strength Rank values are range-dependent, (e.g., the farther a mesocyclone is from the radar, the lower the input strength values needed to have the same strength rank). This parameter is similar to the four regions epicted in the WSR-88D Mesocyclone Recognition Guideline nomogram, except that the NSSL MDA has 25 strength classifications rather than four. The following general information should assist in making warning decisions:

Rank 1 very weak
Rank 3 weak to minimal meso
Rank 5 mesocyclone
Rank 7 strong mesocyclone
Rank 9+ very strong mesocyclone

The highest rank observed in previous tests is 13, but higher ranks are not improbable (Caution: very high Strength Ranks are commonly associated with dealiasing errors, so interrogate the data well). Note that Rank 5 and higher delineates a mesocyclone, and really represents a three-dimensional vortex in which all two-dimensional features meet mesocyclone strength criteria over a continuous depth of 10,000 feet. Rank 5 and higher vortices are coded in red or purple ("hot" colors) in the RADS Mesocyclone Table.

Here are the thresholds to determine the above Strength Ranks for vortices within 60 nm from the radar. One or more of the following must be met across a continuous depth of10,000 feet, and with a base below 18,000 feet:

Rank	Shear(ms-1km-1)	Velocity difference or maximum gate-to-gate (ms-1)
1	3	10
3	4.5	20
5	6	30
7	7.5	40
9	9	50

Intermediate ranks (e.g., 2, 4, 6, 8, 10, 11, 12, ..., 25), are determined using linear interpolation or extrapolation from these values.

Strength Rank values are range dependent. At ranges beyond 120 nm, the shear thresholds are 50% of the thresholds above, and the velocity difference/gate-to-gate thresholds are 75% of the above thresholds. Between the ranges of 60-120 nm, the thresholds decrease linearly from the values in the table above to the lower values at 120 nm.

2) Mesocyclone Strength Index (MSI): A non-dimensional number derived from vertical integration of the Strength Rank. The vertical integration is divided by the depth of the vortex, such that strong shallow vortices (e.g., low-topped mesocyclones) are not misrepresented as being weaker than strong deep vortices. The integration is weighted by density so that measurements closer to the surface are given more significance.

The MSI is similar to a parameter which will be available for the 88D-Meso in Build 10, called the Integrated Rotational Strength (IRS) Index.

In the RADS Mesocyclone Table, the MSI is coded in the following way:

MSI	Color
0 - 2300	(weak) green
2300-3600	(moderate) yellow
>3600	(strong) red

The highest value seen with the very strongest mesocyclones is about 8000.

The NSSL MDA uses several Rule Bases to classify vortices. The 88D-Meso only classifies vortices as uncorrelated shear, 3-D correlated shear and mesocyclones. Instead, the NSSL

MDA uses the following classifications, listed from least to most significant:

Circulation (white): Any detection with a Strength Rank less than 5

Couplet (orange): A "new" detection (no time history) of Strength Rank 5 or greater, having a depth of at least 10,000 feet.

Mesocyclone (red MESO): A detection with time history and a Strength Rank of 5 or greater.

TVSMES (purple): A Mesocyclone associated with a TVS detection from the NSSL TDA

Since the NSSL MDA uses a greater range of strength characteristics to diagnose mesocyclones than does the 88D-Meso algorithm, the NSSL MDA also has the flexibility to add more vortex classifications. For example, there are two "special" classifications:

Low-topped Mesocyclone (red LOWTOP): A detection of Rank 5 or greater, with a base below 10,000 feet, and which does not meet the >10,000 feet depth criteria of a mesocyclone but instead meets a 25% relative depth criteria (relative to the depth of the storm).

Weak Low-topped Mesocyclone (white LOWTOP): A detection of Rank 5 or lesser, with a base below 10,000 feet, and which does not meet the >10,000 feet depth criteria of a mesocyclone but instead meets a 25% relative depth criteria (relative to the depth of the storm).

Shallow Vortex (yellow SHALLW): A detection of Rank 5 or greater, with a top below 10,000 ft. and a base at the 0.5 tilt, whose depth is between 3,000 and 10,000 feet and less than the 25% low-topped criteria.

The colors above are as they appear in the Meso Table. Detections in the table are sorted based on severity, such that all TVSMESs are first, followed by MESOs and LOWTOPs, CPLTs, and then everything else. Secondary and tertiary sorting are done using Strength Rank and MSI, respectively.

RADS allows the user to "filter" the icon display by strength rank. If the user feels there are too many low-ranked vortices on the screen at the same time there are more significant vortices, the user can filter the weaker detections off the display. (These weak detections will remain in the Meso Table.) Suggested filter values would be 1 through 5, depending on the nature of the convective situation.

The color conventions for the icons that are overlaid on the radar images are:

thick yellow with red: Mesocyclone, TVSMES, or Low-Topped Meso with base at 0.5 tilt. Note that the BASE column in the table will also be colored red.

thick yellow: Mesocyclone, TVSMES, or Low- Topped Meso with base above 0.5 tilt.

thin yellow: everything else (weak circulation, couplets, etc.)

Note that Meso Icons and Meso IDs can be displayed separately. At the resolution of some monitors, for small vortices or at low zoom values, the ID numbers can hide the velocity data. In order to see the velocity data, turn the IDs off, or zoom in closer. (Clicking the ID in the Meso Table is the preferred way to zoom in on a particular detection.)

Finally, the center of the meso icon is the center of the vortex at the lowest elevation where it is detected. The size of the icon corresponds to the diameter of the vortex, and is of the same scale as the base radar data image.

An experimental Neural Network (NN) is used to diagnose the Probability of Tornado (POT) or Severe Weather (POSW) for each vortex. The NN uses 23 attributes of the vortex as input, and through a series of intense computations, calculates a Probability of Tornado (POT) and a Probability of Severe Weather (POSW) associated with the vortex. The Neural Network was developed using data from 22 storm days, with verification from Storm Data to assess "ground truth." These 22 days contained a variety of storm-scale vortices, including isolated Southern Plains supercells, mini-supercells from the northeast U.S., Florida storms, and squall-line tornadoes.

It would be helpful to algorithm developers for users to observe the POT and POSW numbers and their trends and see if they provide any useful information for warning decisions. Note that when these values exceed 50%, the columns will be red in the Meso Table.

The NSSL MDA also has time-association features which are not available in the 88D-Meso. Tracks of vortex centers can be displayed using RADS. White dots and lines show the past history (centroids from previous volume scans), and pink crosses and lines show 5-minute incremental forecast positions.

The NSSL MDA and RADS have vortex trends and time-height trends available. These are very useful to evaluate the evolution of the vortex attributes.

4. Other information.

It is important to remember that algorithm products are not available to the user until the end of the volume scan, which is 5-6 minutes later than the lowest-tilt image which can be viewed from that volume scan. Thus, the corresponding low-level centroid position (the position of the vortex closest to the ground) is 5-6 minutes old when it is available for display. This restriction should be taken into consideration when forecasting the position of the radar-indicated tornadoes or severe-weather locations in warnings. For example, use the pink cross-hairs to forecast the position of an element at some time, and not "xx minutes from now."

The NSSL MDA and RADS contain many features which are unavailable in the current WSR-88D package. The goal of creating these features is to provide more information to guide the decisions of warning forecasters. Any feedback which can be provided about the usefulness of the NSSL MDA would be greatly appreciated and would enhance the creation of future versions of the algorithm.

5. References

Stumpf, G.J., A. Witt, E.D. Mitchell, P.L. Spencer, J.T. Johnson, M.D. Eilts, K.W. Thomas, and D.W. Burgess,1998: The National Severe Storms Laboratory Mesocyclone Detection Algorithm for the WSR-88D. Wea. Forecasting, 13, 304-326.

The NSSL Tornado Detection Algorithm (TDA)

1. Purpose

The purpose of this document is to describe the NSSL Tornado Detection Algorithm (TDA), how to interpret the output shown on RADS, and the advantages over and differences between the NSSL TDA and the Tornadic Vortex Signature (TVS) algorithm currently being used with the WSR-88D.

Full details of how information is displayed using RADS is contained within the WDSS User's Manual. The User's Manual should be used as a supplement to this document, particularly the sections on overlays, tables, and trends for the TDA.

2. The Algorithm

The Tornadic Vortex Signature (TVS) is classically defined as a locally intense vortex indicated by strong shear on the order of .01 s-1 between two velocity gates which are azimuthally adjacent and constant in range (gate-to-gate) (Brown et al. 1978). Historically, the NSSL TDA was designed to detect such vortices associated with the non-supercell tornadoes sometimes referred to as landspouts. However, since 1991, the NSSL TDA has been designed and tested using data associated with a wide variety of tornadoes, supercell and non-supercell (Vasiloff 1991, Mitchell 1995, Mitchell 1996).

The NSSL TDA addresses the problem of extremely low probability of detection with the WSR-88D TV algorithm (88D TVS) without a high cost in terms of the false alarm ratio. The NSSL TDA extracts as much information as possible about locally intense vortices within the base velocity data. The algorithm then classifies the vortex as either tornadic or non-tornadic near the end of the processing based upon the overall strength and size of the vortex.

The NSSL TDA uses very low velocity difference thresholds (default 11 m/s) to identify the individual gate-to-gate velocity pairs, or pattern vectors, which are characterized by relatively high shear. The pattern vectors (one-dimensional vortices) are conjugated into two-dimensional vortices, and two-dimensional vortices within 2.5 km of each other in the vertical are three-dimensional vortices. The attributes for each three-dimensional vortex are passed through a rule base which classifies the vortex as either tornadic, potentially tornadic, or non-tornadic. This classification is based upon the depth, strength, and lower extent of the 3D vortex. Furthermore, past track and future position locations are maintained and computed for each detection. Tracking of persistent vortices allows the extraction of trends of important vortex attributes (e.g. maximum low-altitude gate-to-gate velocity difference, depth, base, etc.). According to a recent performance evaluation using a database of about 50 tornadoes, the NSSL TDA has a Critical Success Index (CSI) of 36%, compared to only 3% for the default (TTS = 72 hr -1) 88D TVS.

3. Functional Comparison of the WSR-88D TVS Algorithm and the NSSL Tornado Detection Algorithm.

The current NSSL TDA works independently from all other algorithms and does not require a mesocyclone detection in order to function. Furthermore, the NSSL TDA examines the difference between gate-to-gate velocities, whereas the 88D TVS algorithm calculates the shear between the maximum inbound and outbound velocities within or very near a mesocyclone, regardless of whether the velocity maxima are gate-to-gate. In order to construct a three-dimensional vortex, the NSSL TDA incorporates more stringent vertical association criteria between successive two-dimensional features at different elevation angles than does the 88D TVS. The NSSL TDA also has the advantage of retaining past tracks of persistent vortices and computing a forecast track. In addition, the NSSL TDA provides trends for important diagnostic parameters. Trends of vortices from their incipient stages are possible within the NSSL TDA since very low velocity difference thresholds are used to identify even the weakest vortices prior to becoming tornadic.

The forecaster must be aware of the fundamental difference between the NSSL TDA and the 88D TVS. Namely, these differences are the examination of gate-to-gate velocity differences and the operation of the TDA independently from other algorithms. The NSSL TDA is much more sensitive to detections of weak incipient vortices prior to becoming tornadic than is the 88D TVS. Therefore, the forecaster must be more judicious when using the NSSL TDA as a warning decision tool.

4. The NSSL TDA Output

Output from the TDA is displayed in three ways: diagnostically in the RADS Tornado Algorithm Output table, as overlays on the radar images, and in trend plots.

The following is a description of each column in the Tornado Algorithm Output table, with units where appropriate.

TORNID - tornado identifier, lowercase letters a-z

TYPE - type of tornado detection, classified into two categories:

TVS - Tornadic Vortex Signature: A three-dimensional circulation whose base extends to the 0.5^{o} elevation angle or whose base is below 2,000 ft (600 m) AGL. This type of detection is denoted by a red inverted triangle and is coded red in the Cell and Tornado tables.

ETVS - Elevated Tornadic Vortex Signature: A three-dimensional circulation whose base does not extend to the 0.5o elevation angle and whose base is above 2,000 (600 m) ft AGL. This type of detection is denoted by a yellow inverted triangle and is coded yellow in the Cell and Tornado tables.

Note: The user may specify whether the ETVS detections are to be displayed with the TVS_PLOT_ETVS_ONLY variable in the ssaparm.dat file. Setting this variable to true (T) specifies that only TVS type detections are to be displayed; setting it to false (F) displays both ETVS and TVS detections.

TVS (and ETVS) detections are displayed in the NSSL Cell Algorithm Table under the CIRC column if the detection is associated with a SCIT-identified storm cell. If a TVS is associated with a mesocyclone, then it is displayed in the Cell table as a TVSMES.

AZ/RAN - Azimuth and range of the centroid of the base of a TVS or ETVS (degrees/km, nm).

CELLID - Cell ID of the closest storm identified by the NSSL Storm Cell Identification and Tracking (SCIT) algorithm.

MESOID - Mesocyclone ID of the closest associated mesocyclone detected by the NSSL Mesocyclone Detection Algorithm. A cyan-colored box in this column indicates an associated mesocyclone ID; a green-colored box indicates no associated mesocyclone.

BASE - Altitude ARL of the base of a TVS or ETVS (km, kft).

TOP - Altitude ARL of the top of a TVS or ETVS (km, kft).

DEPTH - The overall depth of a TVS or ETVS (km, kft).

LA GTG - The maximum low-altitude gate-to-gate velocity difference at the base of a detection (m/s), color-coded in the following manner:

RED: velocity difference > 40 m/s

YELLOW: velocity difference 20-39 m/s

GREEN: velocity difference < 19 m/s (but not below the minimum velocity difference) Note: The minimum velocity difference that will be displayed is determined by setting the TDA_GTG_THR variable in the adaptable parameter (ssaparm.dat) file. It is recommended that the minimum gate-to-gate velocity difference threshold not be set below 10 m/s. The default minimum velocity difference threshold is 11 m/s.

MX GTG - Maximum gate-to-gate velocity difference within a three-dimensional circulation (m/s), color-coded in the following manner:

RED: velocity difference > 40 m/s

YELLOW: velocity difference 20 - 39 m/s

GREEN: velocity difference < 19 m/s (See preceding Note)

DIR/SPD - Direction and speed of motion of TVS or ETVS (degrees/m s-1, kts).

TDA detections are sorted in the table based on severity. The order of the sort is such that all TVSs are sorted above ETVSs (if ETVSs are displayed). The secondary sort is based upon the maximum low-altitude gate-to-gate velocity difference.

Each detection location, past track, and forecast track are displayed by overlays onto the radar data images. The current location is indicated by the center of an inverted red triangle for a TVS or a yellow inverted triangle for a ETVS. The past track is indicated by white dots and the forecast track is indicated by the magenta cross-hairs. A maximum of ten past tracks (approximately one hour) can be displayed for each detection. The forecast positions indicate the computed position at five minute intervals. The number of forecast positions which are displayed (up to six) equals the number of past track positions, for approximately a 30-minute forecast. Currently, the direction and speed are based upon the current and previous signature locations. If the detection is new, the direction and speed are determined (in rank order) from 1) an average motion vector of detections from the previous volume scan, 2) the nearest storm motion vector or 3) a default motion vector. **Be aware that the NSSL TDA tracks all identified circulations. Therefore, if the option to display a TVS only is specified then the past identified circulations may have been either TVSs or ETVSs. In other words, a TVS track does not imply that the entire track consists of TVS classified circulations.**

Finally, diagnostic information is provided in trend plots. Trends may give a forecaster valuable guidance about whether a circulation is strengthening, weakening and/or descending or ascending. The TORN trend set contains time-series plots of the altitude of the base, the depth of the detection, the low-altitude gate-to-gate velocity difference, the maximum 3D gate-to-gate velocity difference, and the height of the maximum velocity difference. A trend plot of the altitude of the top of the detection as well as the trends comprising the trend set are also available in the single trend window.

4. Other information.

It is important to remember that algorithm products are not available to the user until the end of the volume scan, which is 5-6 minutes later than the lowest-tilt image which can be viewed from that volume scan. Thus, the corresponding low-altitude centroid position (the position of the TVS closest to the ground) is also 5-6 minutes old when it is available for display. This restriction should be taken into consideration when forecasting the position of the radar-indicated tornadoes in warnings. For example, use the pink cross-hairs to forecast the position of an element at time HHMM, and not “xx minutes from now”.

The forecaster must exercise caution when interpreting the NSSL TDA output. Because the TDA is more sensitive to detection of weak circulations than the 88D TVS, forecasters must be more judicious in deciding whether to issue severe thunderstorm or tornado warnings. It is highly advisable that *ALL* available data be considered along with the TDA guidance when making a warning decision. Other information such as the presence of a pendant/hook echo protruding from the rear flank of the storm, (bounded) weak echo region [(B)WER] and the merger/collision between a storm and a surface boundary (i.e., storm outflow gust front, mesoscale boundary, etc.). Remember, the NSSL TDA does NOT consider reflectivity structure.

The algorithm has been tested using a data set consisting of tornadoes within 150 km of a WSR-88D. However, it is not necessarily recommended that the NSSL TDA be used to identify tornadic circulations at this extreme range. Instead, 100 km may be a more appropriate maximum range for the NSSL TDA to more reliably identify tornadic circulations.

Also, remember that due to limitations of the radar, especially beam broadening with range, that the actual vortex associated with the tornado may not be sampled. For example, a mesocyclone at far ranges (> 100 km) may appear “TVS-like.” If the tornado is very large and close (within 15 km) to the radar the tornado may be sampled by more than two adjacent radar beams and appear “mesocyclone-like”.

Recent evidence has led NSSL scientists to believe that the tornado may only be sampled in rare cases and that it is the tornado cyclone (an intermediate vortex between the tornado and mesocyclone) or the mesocyclone which is actually detected by the NSSL TDA (Mitchell and Stumpf 1996, Rasmussen and Straka 1996, Straka et al. 1996). The case study by Mitchell and Stumpf (1996) observed a small-scale vortex (presumably the tornado cyclone) embedded within a mesocyclone, and other observations of near range tornadoes appear to support such structure.

In the case of near-range tornadoes that may go undetected by the NSSL TDA, it is suggested that a forecaster pay particular attention to any mesocyclone or mesocyclone-like (tornado cyclone) signatures in the base velocity and reflectivity data. The NSSL Mesocyclone Detection Algorithm may be useful in these cases in identifying the .broad-scale vortices (tornado cyclone or mesocyclone) and thus may provide useful guidance about the significance of the vortex and its tornadic potential.

The NSSL TDA and RADS contain many useful features which are unavailable in the current WSR-88D package. The goal of creating these algorithms is to provide better information to help guide the warning decisions faced by NWS forecasters. Any feedback which is provided about the usefulness of the NSSL TDA is encouraged and greatly appreciated, and will enhance the creation of future versions of the algorithm.

5. References.

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Vasiloff, S.V., 1991: The TDWR tornadic signature detection algorithm. Preprints, 4th International Conference on Aviation and Weather Systems, Boston, Amer. Meteor. Soc., J43-J48.

Bounded Weak Echo Region (BWER) Algorithm

1. Purpose

The BWER Detection Algorithm is briefly described below. The WDSS User Manual, especially the sections on overlays and cross-sections, should be used as a supplement to this documentation. In addition, a description of the NSSL BWER Detection Algorithm appears in the May issue of "AI Applications". Note that the journal paper is considerably out of date: the version of the BWER scheme tested in real-time during 1997 does not use NSSL Mesocyclone Detection Algorithm (MDA) output and takes storm motion information into consideration.

2. Background

A Bounded Weak Echo Region (BWER) is a region of relatively low radar reflectivity which extends upward into, and is surrounded by, higher reflectivities aloft. Sometimes called a "vault," this radar signature is usually indicative of a high speed updraft. Such a strong updraft (with speeds of around 50 m/s) is so fast that the processes forming precipitation cannot operate rapidly enough to develop high radar reflectivities until the air parcels have ascended to relatively great heights.

As radar elevation scans sample through a BWER, the BWER first appears as a region of relatively low reflectivities surrounded by higher reflectivities and then, at higher elevation angles, becomes "capped" by a broad region of high reflectivity.

3. Algorithm methodology

The entire reflectivity elevation scan is searched for local minima. Unlike earlier versions, Mesocyclone Detection Algorithm (MDA) information on circulations is not used to narrow the search.

The algorithm searches for local minima in radar elevations scans as they come in, then vertically stacks the images and fits all possible three-dimensional updraft structures to the found minima and high-reflectivity ("capping") regions. The elevation scans are adjusted for storm motion using storm motion information from the NSSL SCIT algorithm.

A single local minimum could be part of several candidate updraft structures. Fuzzy logic is used to combine the attribute values of all these three-dimensional structures into one value. Thus, each candidate 2D region will have a set of attributes (like partial VIL, capping, value of local minimum etc.). Based on these attributes, a candidate region is classified either as a BWER or as a non-BWER, again using fuzzy logic.

4. Algorithm output

All BWERs found are displayed on RADS at the location at which they are detected. Detected BWERs are color-coded according to the algorithm's confidence level — green denotes a 50-60% confidence level, yellow a 60-80% level and red a confidence greater than

80%. In general, the higher the confidence level, the more intense the updraft.

The algorithm products are available a few seconds after the end of the fifth elevation scan of a volume in VCP 21 (ninth scan for VCP 11). Until then, RADS displays the previous volume scan information. This should be taken into account when forecasting the position of the radar-indicated BWERs in warnings.

Since the BWER is a three-dimensional updraft structure, the reflectivity images alone are not enough to visualize the structures. It is recommended that several cross-sections be taken through the BWER location. The BWER "vault" should be clearly visible in at least one of the cross-section images.

Any feedback from users concerning the utility of this documentation and the NSSL BWER algorithm is greatly appreciated. Your suggestions and comments will help to enhance the algorithm.

5. References

Lakshmanan, V., and Arthur Witt, 1997: Automatic detection of bounded weak echo regions. Preprints, 28th Conference on Radar Meteorology. Austin, TX, Amer. Meteor. Soc., 366-367.

Damaging Downburst Prediction and Detection Algorithm (DDPDA)

1. Purpose

Full details of how information is displayed using RADS is contained within the WDSS User Manual. The User Manual should be used as a supplement to this document, particularly the sections on overlays, tables, and trends for the DDPDA.

2. The Algorithm

The NSSL DDPDA was initially developed in 1994 based on data from the Phoenix, Arizona, WSR-88D, and has since been used in a variety of real-time tests. The algorithm is being developed to fill a void in the current suite of WSR-88D algorithms, since the WSR-88D system presently does not have the capability to detect or predict damaging straight-line wind events.

Four types of output are produced by the algorithm: low-altitude divergence signature detection, downburst prediction, images of radial divergence, and the trend of downburst precursor information. The current version of the algorithm has been developed to focus on severe wind events produced by isolated cells; a version that is capable of handling straight-line wind events produced by phenomena such as derechos is planned for a future release.

3. Use of output in making warning decisions

DDPDA information can be found in the BURST column of the cell table and as an icon in the RADS product windows. The following display conventions are used:

TYPE	TABLE IDENTIFIER	OVERLAY ICON
Severe Detection	SEVDET	solid cyan icon with “S” in the middle
Moderate Detection	MODDET	solid aqua icon with “M” in the middle
Severe Prediction	SEVPRD	hollow aqua icon with “S” in the middle
Moderate Detection	MODPR	hollow aqua icon with “M” in the middle
Elevated Core	HICORE	none
Severe Convergence	SEVCNV	none

Severe” detections and predictions are issued for those cells capable of producing wind speeds in excess of 50 kts, while “Moderate” detections and predictions are issued for cells which are capable of producing wind speeds in excess of 30 kts.

Overlay icons are positioned at the storm centroid and not over the downburst signature. For this reason, and because the cyan color is easier to view over velocity data, it is advised to display the icons over the velocity images and not the reflectivity images.

The cell time-height trends, available as pop-up menus on the reflectivity and velocity images, may help forecasters assess downburst potential. The five trends available in the cell time-height menu are:

MAXIMUM REFLECTIVITY - a profile of the maximum reflectivity in the cell.

REFLECTIVITY CORE - a plot of the reflectivity "cores" which meet a cross-sectional area threshold of 10 km2 (at 5 dBZ increments).

CONVERGENCE - a profile of radial convergence, expressed as velocity differences.

DIVERGENCE - a profile of radial divergence, expressed as velocity differences.

CON/DIV PROFILE   a combined profile of the Convergence and Divergence profiles created by using the point with the greatest absolute value at each height. Positive values represent radial divergence, while negative values represent radial convergence.

In particular, cells which have (1) a rapidly descending reflectivity core which often develops at a higher altitude (an "elevated core") than in other, non-downburst-producing, cells; (2) strong and deep convergence between roughly 6000 ft and 24000 ft above ground level; and (3) rotation in the deep convergence level (in some cases) have been shown to produce damaging downbursts.

DDPDA detects these precursors within a cell and uses a "fuzzy logic" rule base to decide whether to issue a downburst prediction for the cell. This rule base is range-dependant, with radial velocity parameters being more important within about 40 nm of the radar, while reflectivity parameters are more heavily weighted at longer ranges. A "HICORE" condition is displayed in the BURST column of the cell table when the high-reflectivity core has been detected at an altitude above 8 km. An elevated core is frequently the earliest precursor for downbursts. A recent evaluation of the algorithm based on 226 "pulse"-type cells and 30 severe downbursts from diverse geographic locations yielded the following performance statistics:

H Hits	**M** Misses	**FA** False Alarms	**CN** Correct Null Events	**POD** Probability of Detection	**FAR** False Alarm Ratio	**CSI** Critical Success Index	**HSS** Heidke's Skill Score	**Lead** Lead Time (Minutes)
20	10	21	175	0.667	0.512	0.392	0.566	8.5

The cells used in the study were taken from populated areas only in order to reduce the uncertainties associated with determining the actual severity of cells which may have not been witnessed by anyone.

The core descent, convergence aloft, and low-altitude divergence can be viewed by opening time-height trend windows for "Reflectivity Core" and "Conv/Div Profile." Preliminary research has shown that convergent velocity differences aloft of 50 kts or greater have a high probability of being associated with severe weather at the surface (Schmocker et al 1996). When this condition is met, "SEVCNV" will appear in the BURST column of the cell table, unless a downburst prediction or detection is already in effect for that cell.

A "Burst" trend set is also available in RADS, which gives a concise analysis of each cell's downburst potential in a compact format. The trend set includes maximum convergence, depth of maximum convergence, storm-top divergence (if available), and height of the center-of-mass and
maximum reflectivity plots. The center-of-mass height and height of maximum reflectivity plots can be used to assess reflectivity core descent, but are sometimes misleading and can give a signal that is less clear than in the Reflectivity Core time-height trend.

4. Other information

It is important to remember that algorithm products are not available to the user until the end of the volume scan, which is 5-6 minutes later than the lowest-tilt image which can be viewed from that volume scan. Thus, the corresponding storm centroid position is also 5-6 minutes old when it is available for display. Also, the DDPDA icons are placed over the cell centroids, and not necessarily the location of the downburst. This detail is important to remember when forecasting the position of the storms in warnings. For example, use the pink cross-hairs to forecast the position of an element at time HHMM rather than "xx minutes from now," and study the velocity data for the downburst signatures.

IMPORTANT: The DDPDA should primarily be used for prediction and detection of downburst events that occur in a "low-shear" environment. Depending on the environment, you should change a variable in the ssaparm.datparameter file. For a "low-shear" (pulse thunderstorm) environment, set NSE_TYPE_DDPDA equal to P (for "pulse"). If bow echoes or supercells are expected, set NSE_TYPE_DDPDA equal to B (for "bow echo").

The NSSL DDPDA and RADS have many features that are unavailable in the current WSR-88D package. The goal of creating these algorithms is to provide better information to guide the decisions of warning forecasters. Any feedback about the NSSL DDPDA would be greatly appreciated.

More information on the DDPDA can be found on the World Wide Web at the address: http://www.nssl.noaa.gov/~tsmith/ddpda.

5. References

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Smith, T. M., 1997: Prediction and detection of damaging downburst events with the WSR-88D. Preprints, 28th Conf. on Radar Meteorology, Austin, TX, Amer. Meteor. Soc., pp. 376-7.

Near-Storm Environment (NSE) Algorithm

The NSE algorithm associates near-storm environmental data with storm cells. The NSE data are obtained using the National Center for Environmental Prediction (NCEP) Rapid Update Cycle (RUC-II) model data. Currently, the NSE algorithm analyzes gridded thermodynamic data as input into the HDA in the form of the height of the 0° and -20° C isotherms. NSE also computes an environmental helicity grid which is used to compute 0-3 km AGL Storm-Relative Environmental Helicity (SREH) values for each storm cell which is displayed in the Cell Table and trend displays. The NSE also calculates the mean storm cell motion which is used as the “first-guess” for cell-mesocyclone-, and tornado-motion estimates.

Lightning Association Algorithm (LAA)

Lightning strike information is being used more often in operational settings (Holle and Lopez 1993). There are numerous hypotheses which relate the time series of lightning strikes with the evolution of storms. The NSSL Lightning Association Algorithm (LAA) integrates the National Lightning Detection Network data with the WSR-88D radar data by associating lightning ground strikes with identified storm cells detected by the SCIT Algorithm. Diagnostic information is displayed in the Cell Table under two attributes: 1) total (positive and negative polarity) lightning flash rate (normalized to 5 minutes) and 2) percentage of positive lightning strikes. Trends of these and additional storm/lightning attributes are also produced and are available along with information from the SCIT Algorithm. Lightning ground strike locations can also be plotted using RADS.

WSR-88D Precipitation Algorithms

The WSR-88D Precipitation Algorithm is available with the WDSS. Area-wide accumulated one-hour, three-hour, and storm-total precipitation images are available for display on RADS. The WSR-88D Precipitation Algorithm takes advantage of an enhanced clutter residue editing map available with the WDSS, and in some situations, accumulation information is more accurate.

Vertically Integrated Liquid (VIL) Algorithm

The gridded VIL Algorithm is available with the WDSS. Reflectivity data is averaged over a 4 km^2 area and integrated in the vertical to create the VIL value. The gridded VIL values are different from the "cell-based" VIL values that are calculated in the Storm Cell Identification and Tracking (SCIT) algorithm. The cell-based VIL values are an integration of the liquid water content comprised of the maximum reflectivity values from each observed elevation in a storm. The cell-based VIL value will thus be inherently higher than the gridded VIL values. The trends of VIL that are available in WDSS are cell-based VIL and not grid-based.

Viewing NSSL Algorithm Output: Predictions and Detections

Output from the NSSL suite of severe weather detection algorithms may be viewed in three different ways:

1. *Graphically*, as algorithm output overlays ("icons") on images, Customized icons for each type of algorithm output are displayed on radar data. See Chapter 3 for more information on algorithm overlays.
2. *Tabular form*, by pressing one of the Output Table buttons on the RADS control panel. When this option is chosen, a table of information on the storm cells, mesocyclones, or tornadoes are displayed in order of severity. Information is also color coded for strength rank and classification.
3. *Trends, trend sets* and *time-height trends*, where characteristics of meteorological phenomena are graphically displayed as functions of time. See Chapter 3 for more information on trends.

The graphical forms, tables, and trend sets are all different methods of displaying information about storm cells, hail, mesocyclones, and tornadic activity and are complementary. By examining the position of an item of interest on the image, the user may note the associated identification number and then reference the corresponding information on the table output. Or, the user may choose an appropriate trend or trend set. This chapter gives detailed information on the overlays tabular output of the NSSL meteorological algorithms. More information about overlays, trends, trend sets, and time-height trends are found in Chapter Five.

Note that in all tabular output, the detections are ranked in severity, with the **topmost detection being the most severe.** Detections located lower in the tables, then, are of lesser severity according to the assessment of the meteorological algorithms. Up to 20 cells are displayed in the Cell table, and up to 15 detections are displayed in the Meso and Torn tables.

Table entries are also **color coded to quickly provide special information** such as type of circulation, strength of surface winds, etc. **Red** colors always indicate phenomena that are most severe, **yellow** items are moderate in strength, and **green** items indicate little or no severity. Items in white are parameters with no color coding (e.g., Storm motion). Refer to the information in this chapter to further decode this tabular data with specific ranges of values, if appropriate. Other colors are used to classify data such as circulation type.

Examples of Tabular Data

On the following pages are examples of algorithm output tables.

Note: You may quickly zoom to any mesocyclone, storm cell, or tornado identified in the severe weather algorithm output tables. SIMPLY CLICK ON THE IDENTIFICATION NUMBER OF THE OBJECT IN THE LEFT COLUMN. All active image windows will then zoom (4X) to that object of interest.